DEVELPOMENT OF A COMPREHENSIVE EXCEL SPREADSHEET FOR ESTIMATING THE OUTPUT OF SOME GEOTECHNICAL LABORATORY EXPERIMENTS

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Submitted by

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CERTIFICATE

National Institute Of Technology

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This certificate is to state that “**DEVELPOMENT OF A COMPREHENSIVE EXCEL SPREADSHEET FOR ESTIMATING THE OUTPUT OF SOME GEOTECHNICAL LABORATORY EXPERIMENTS**” is an original and sincere work carried out by **Jyotishman Mudiar** under my supervision in partial fulfilment of the degree of Bachelor of Technology under the Dept. of civil engineering, NIT Rourkela, Odisha.

It is also certified that the work of this project has not been submitted elsewhere for the award of any degree or diploma.

Place: Rourkela

Date:

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Abstract

Geotechnical laboratory experiments are vital in determining the geotechnical properties of soil. These tests are generally performed for a number of times to obtain the best result and in most of the times, to average them to minimize the deviation in output. Hence to execute the process calculation is a tedious and hectic process, especially when the number of experiments is large or the steps of calculations are lengthy. Besides, the availability of software and spreadsheets to obtain accurate output is very rare in literature, and the few that are there are too in-comprehensive and incomplete dealing just a few of the many laboratory experiments that the entire geotechnical engineering is concerned.

The work in this project is an honest effort to minimize the effort involved in the different Civil engineering laboratory experiments carried out at different institutes and construction sectors by designing a Microsoft Excel Spreadsheet that determines the output of the different geotechnical laboratory experiments along with the graph of related parameters wherever necessary. The process, procedure, input parameters and the calculations have been followed as per the Indian Standard Codes of Geotechnical Engineering. In cases, where the size of the apparatus or the related constants vary from place to place, the input columns have been provided where the different input can be incorporated in order to obtain the corresponding result.

The excel spread sheet has been designed to make it a generalized one so that the utility of this spread sheet can be availed irrespective of variation in location and instruments. For all practical reference during the work, the Geotechnical Engineering Laboratory of NIT Rourkela has been used and the output has been tested on a number of inputs that were obtained in different experiments done at NIT Rourkela. The result obtained has been found consistent. Also a few inputs of the book, “Principles Of geotechnical Engineering” by B M Das and “Soil Mechanics and foundations” by B C Punmia, Ashok Kr. Jain, Arun Kr. Jain have been tested and found consistent.

Hence, this Microsoft Excel Spread sheet can be judiciously used in minimizing effort and obtaining the most accurate outputs in various laboratory experiments in Geotechnical Engineering.

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In general soil is a later stage of rock cycle when withered successively. They are aggregates of mineral particles, and together with air or water or both in the void spaces, form the three phase system The different physical properties of soil depends on different factors like the type of minerals that constitute them, the physical conditions they are subjected to, the extent of withering the rock cycle has reached etc. Based on these factors, soil exhibits different geotechnical properties. Grain-size distribution, specific gravity, water content, cohesion, load bearing capacity are a few common properties that we come across in all aspects of geotechnical engineering.

Geotechnical Engineering is a branch of civil engineering that involves materials found close to earth's surface. It includes the application of soil mechanics in design of different structures like foundations, retaining structures, earth structures, embankments etc.

In the ancient times, the geotechnical engineering was based on the artistic perspective and the perceptions based on past experiences. The true geotechnical engineering came after Skempton, 1985 which not only mitigated many common flaws that used to occur frequently in design structures of the past, but also led to the invention of many wonderful engineering marvels. This modern geotechnical engineering is based on detailed laboratory experiments for the determination of different geotechnical properties of soil used in construction sites.

These geotechnical properties play vita roles and are of immense utility in all the construction sectors like roads, embankments, bridges, buildings etc. They play a significant role in determining the sustainability and stability of a structure, in determining the different types of design to be used corresponding to different sites, in selecting construction sites, in estimating the types of landfill liners or geo-synthetics to be used in low lying areas etc.

Hence, the laboratory experiments of the geotechnical properties are significant and vital to every construction sector.

The objective of this project work is to design a comprehensive excel spread sheet that can estimate the output of some geotechnical laboratory experiments with less effort and utmost accuracy.

The scope of this work is that it can be used effortlessly and effectively in different geotechnical engineering institutes and construction sectors to obtain the output in experiments for which the spread sheet has been developed.

3.1

LIQUID LIMIT (LL) : *(IS 2720-part 5, 1985.)*

The moisture content at the point which transmission from plastic to liquid state takes place in a soil system is the liquid limit.

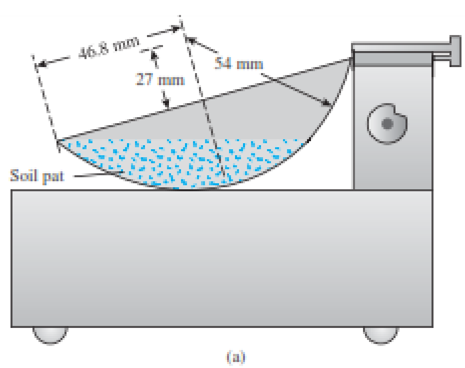


Fig 3.1(a) Liquid Limit Apparatus (Das, B. M., 2010)

To perform the liquid limit test, one must place a soil paste in the cup. A groove is then cut at the center of the soil pat with the standard grooving tool. The moisture content, in percent, required to close a distance of 12.7 mm (0.5 in.) along the bottom of the groove after 25 blows is defined as the liquid limit. The relationship between moisture content and log N is approximated as a straight line. This line is referred to as the flow curve (Das, B. M., 2010). The moisture content corresponding to N=25, determined from the flow curve, gives the liquid limit of the soil. The slope of the flow line is defined as the flow index and may be written as

$$I_F = (w_1 - w_2)/\mathrm{Log}(N_2/N_1)$$

Where I_F= flow index

w represents water content, N represent number of blows.

EXCEL SPREAD SHEET DEVELOPMENT

Input parameters:

1. Weight of moist soil+ tin =B
2. Weight of dry soil+ tin=C
3. Weight of tin=D
4. Number of blows=H

Output parameters:

1. Weight of dry soil=C-D=E
2. Weight of water=B-D-E=F
3. Moisture Content=F*100/E=G
4. Flow Index=obtained from slope of curve:
5. Liquid Limit. = water content corresponding to 25 blows.

   Algorithm to get as the cell output.

   Step: 1: Moisture content G is obtained for 5 different inputs and is averaged.=y_1.

   Step: 2: Number of blows H is taken corresponding to the 5 inputs,averaged =x_1

   Step 3: slope is calculated by taking G as ordinates and H as abscissas, then averaged=m

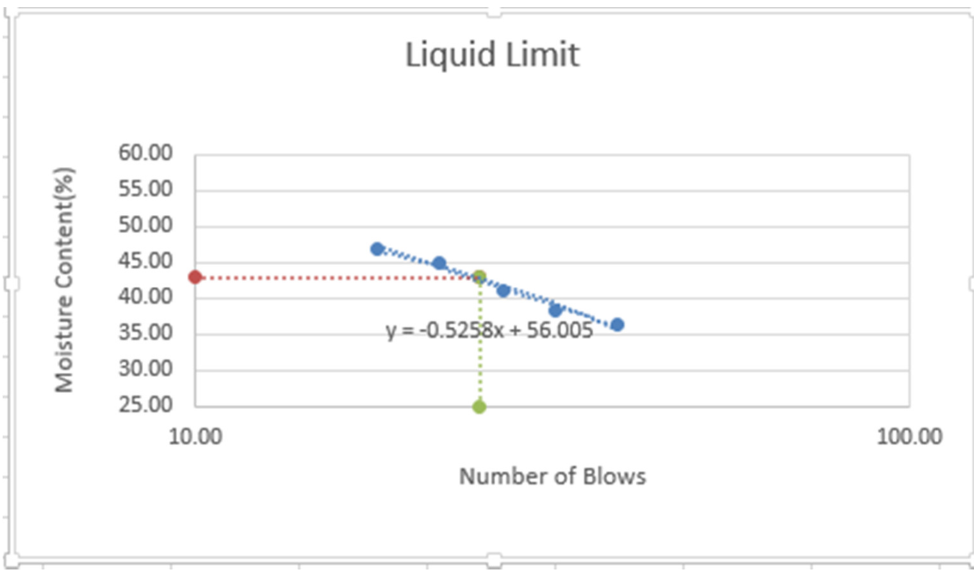
   Step 4: LL= y_1+m*(25-x_1)

Snapshot of designed spread sheet (table 3.1)

IS 2720-part 5 (1985)

Observation number	Wt of moist soil+ tin	Wt of dry soil+tin	Wt of tin	Wt of dry soil	Wt of water	Moisture content(%)	Number of blows	Slope	Liquid Limit
1.00	43.40	33.60	12.70	20.90	9.80	46.89	18.00	-0.50	42.82
2.00	34.00	27.40	12.70	14.70	6.60	44.90	22.00	-0.76	
3.00	27.80	23.40	12.70	10.70	4.40	41.12	27.00	-0.59	
4.00	32.60	27.10	12.70	14.40	5.50	38.19	32.00	-0.26	
5.00	26.20	22.60	12.70	9.90	3.60	36.36	39.00	-0.45	
					Avg	41.49	27.60	-0.51	

Output Flow Curve:



3.2 SHRINKAGE LIMIT:

The moisture content, in percent, at which the transition from solid to semisolid state takes place is defined as the shrinkage limit.

Shrinkage limit tests are performed in the laboratory with a porcelain dish about 44 mm (1.75 in.) in diameter and about 12.7 mm (in.) High. Excess soil standing above the edge of the dish is struck off with a straightedge. The mass of the wet soil inside the dish is recorded. The soil pat in the dish is then oven-dried. The volume of the oven-dried soil pat is determined by the displacement of mercury. The wax-coated soil pat is then cooled. Its volume is determined by submerging it in water (Das, B. M., 2010).

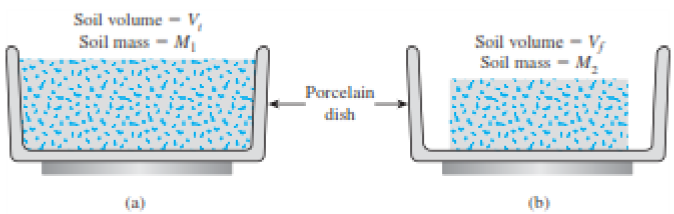


Fig. 3.2: A schematic diagram of apparatus of shrinkage limit test (Das, B. M., 2010)

Shrinkage limit can then be calculated by the formula given below

$SL= ((M_1-M_2)/M_2)*100- ((V_i-V_f)/M_2)*D_w*100$

Where M_1= mass of wet soil pat in dish in beginning

M_2= mass of dry soil pat

V_i=initial volume of wet soil pat

V_f= final volume of oven dried soil

D_w= desnity of water.

EXCEL SPREAD SHEET DEVELOPMENT

Input parameters

1. Weight of shrinkage dish + wet soil =A
2. Weight of dish+ dry soil =B
3. Weight of dish alone=C
4. Weight of mercury to fill dish=D
5. Weight of mercury displace by dry soil=F

Output parameters

1. Original volume of wet soil=E=D/13.6
2. Dry volume of soil=G=F/13.6
3. Initial moisture content (%)=H=100*(A-B)/(B-C)
4. Shrinkage Limit=SL= (H-100*(E-G)/(B-C))

   **average of 4/5 experiments are taken to minimize deviation.*

   Snapshot of the excel spreadsheet determined for shrinkage limit(table 3.2)

	A	B	C	D	E	F	G	H	I
1	Aim : To determine the shrinkage Limit of a soil sample								
2	IS 2720-part 6 (1972)								
3	Weght of shrinkage dish + wet soil (gm)	weight of dish + dry soil (gm)	weight of dish alone (gm)	Weight of mercury to fill dish (gm)	original volume of wet soil (cc)	Weight of mercury displaced by dry soil (gm)	Dry volume of soil (cc)	Initial moisture content (%)	Shrinkage limit (%)
4	102.12	94.48	64.52	343.00	25.22	284.00	20.88	25.50	B4-C4))
5	102.00	94.00	64.52	342.00	25.15	283.00	20.81	27.14	12.42
6	103.00	95.00	64.52	342.50	25.18	285.00	20.96	26.25	12.38
7	103.50	95.50	64.52	341.00	25.07	286.00	21.03	25.82	12.77
8	104.00	96.00	64.52	344.00	25.29	287.00	21.10	25.41	12.10
9							Avg Shrinkage Limit		12.14

3.3 SPECIFIC GRAVITY (G):

Specific gravity is defined as the ratio of the unit weight of a given volume of dry soil in air to the unit weight of equal volume of distilled water at 27^0C (Das, B. M., 2010).

In laboratory, the soil sample is taken in a bottle of known weight and the soil in weighed. Then water is poured to half the mark and shacked well to blow out the air and then filled to the top and weighed. Next soil-water mixture is thrown and water is poured into it and weighed.

Specific gravity G is obtained by: $w_1/ (w_1-w_3+w_2)$

Where w_1= weight of soil

w_2=weight of bottle +soil+ water

w_3=weight of empty bottle +water.

EXCEL SPREAD SHEET DEVELOPMENT

Input parameters

1. Mass of empty bottle=A
2. Mass of empty bottle+ soil=B
3. Mass of bottle+ soil+ water=C
4. Mass of bottle+ water= D
5. Specific gravity G= (B-A)/((B-A)-(C-D))

Snap shot of the excel spread sheet determined for specific gravity(table 3.3)

Aim: To determine specific gravity of a soil passing through the 4.75 IS sieve using density bottle

IS 2720-part 3 (1980)

Mass of empty bttle (gm)	Mass of bottle+ soil (gm)	Mass of bottle+soil +water (gm)	Mass of empty bottle+water (gm)	specific gravity (G)
60.00	110.00	375.00	345.50	2.44
60.00	110.00	375.50	347.20	2.30
60.00	110.00	376.00	348.00	2.27
60.00	110.00	378.00	348.50	2.44
60.00	110.00	380.00	349.00	2.63
60.00	110.00	381.00	349.50	2.70
60.00	110.00	382.00	350.00	2.78
		Avg (specific gravity)		2.51

3.4 LIGHT COMPACTION TEST:

In the Proctor test, the soil is compacted in a mold that has a volume of 944 cm^3. The diameter of the mold is 101.6 mm. During the laboratory test, the mold is attached to a baseplate at the bottom and to an extension at the top (Figure 3.4 a, b). The soil is mixed with varying amounts of water and then compacted in three equal layers by a hammer that delivers 25 blows to each layer. The hammer has a mass of 2.5 kg and has a drop of 30.5 mm (Das, B. M., 2010).

The moist unit weight can be calculated by $\Upsilon_d = W/V$

Where W=weight of compacted soil in mold

V=volume of the mold.

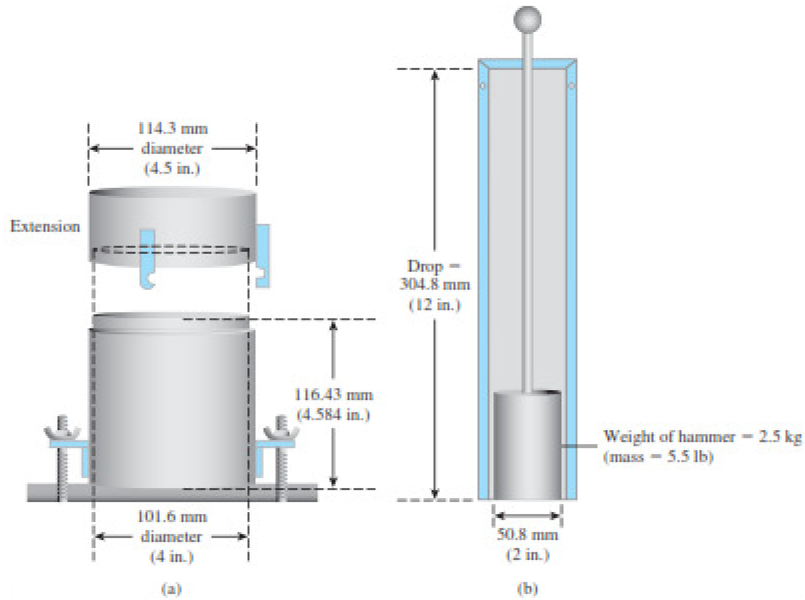


Figure 3.4 A schematic diagram of apparatus of a standard proctor test (*adapted from "principles of geotechnical Engineering" B M Das)*

EXCEL SPREAD SHEET DEVELOPMENT

Input parameters

1. Weight of container= A
2. Weight of wet soil+ container=B
3. Weight of container+ dry soil= C
4. Weight of mold=F
5. Weight of mold +wet soil=G

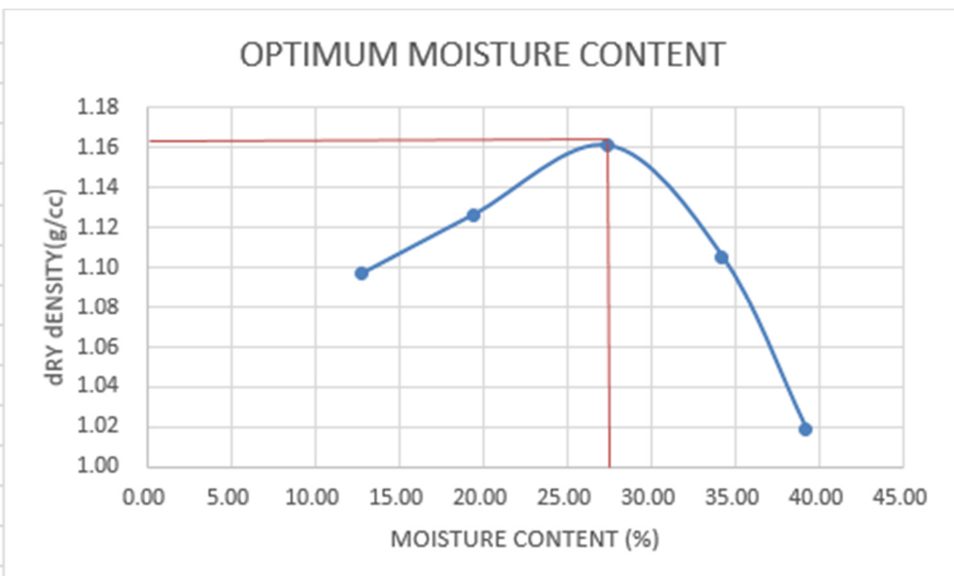
   Output parameters

   1. Water content=D= (B-C)*100/(C-A)
   2. Dry density Υ_d = (G-F)*0.001/(1+(D*0.01))

Snapshot of the excel spread sheet designed for standard proctor test(table 3.4)

	A	B	C	D	E	F	G
1	IS code: 2720, part7, 1980,(reaffirmed in 1987)						
2	CONTAINER	CONTAINER+	CONTAINER+	w	γ_d	MOULD	MOULD+
3	WT (g)	WET SOIL (g)	DRY SOIL (g)	(%)	g/cc	(g)	WET SOIL (g)
4	20.94	124.38	112.61	12.84	1.10	1838	3076
5	20.90	104.34	90.74	19.47	1.13	1838	3184
6	20.90	130.15	106.61	27.46	1.16	1838	3318
7	20.47	179.20	138.71	34.24	1.11	1838	3322
8	20.54	136.21	103.62	39.23	1.02	1838	3257

Curve obtained from the above spread sheet.



<u>3.5 CORE CUTTER METHOD TO EVALUATE IN-SITU DRY DENSITY:</u>

This test is done to determine the in-situ dry density of soil by core cutter method as per IS: 2720 (Part XXIX) – 1975

Fig 3.5 (a)

Procedure to determine the In-Situ Dry Density of Soil by Core Cutter Method

i) The internal volume (V) of the core cutter in cc should be calculated from its dimensions which should be measured to the nearest 0.25mm.

ii) The core cutter should be weighed to the nearest gram (W1).

iii) The cutter containing the soil core should be weighed to the nearest gram (W2).

iv) The soil core should be removed from the cutter and a representative sample should be placed in an air-tight container and its water content (w).

Formulas used

Bulk density of the soil g/cc ϒ = [W2 – W1]/ V g/cc

Dry density of the soil g/cc ϒd = 100Y/[100+w] g/cc

EXCEL SPREAD SHEET DEVELOPMENT

Input parameters:

1. Weight of core cutter=A

2. Weight of core cutter with soil=B
3. Weight of moisture=C
4. Volume of core cutter=E

Output parameters:

1. Weight of weight soil=D
2. Bulk Density= D/E

Snapshot of the excel spread sheet designed for core cutter method (3.5)

	A	B	C	D	E	F	G
1	Aim : To determine the field density by core cutter method						
2	IS 2720-part 28 (1975)						
3	Wt of cone cutter (gm)	wt of cone cutter with soil (gm)	wt of moisture (gm)	wt of wet soil(gm)	Volume of cone cutter (cc)	bulk Density (gm/cc)	bulk unit weight KN/m^3
4	931.00	3178.00	22.00	2247.00	1178.10	1.91	18.71
5	930.00	3111.00	21.00	2181.00	1178.00	1.85	18.16
6	920.00	3110.00	23.00	2190.00	1170.00	1.87	18.36
7	929.00	3201.00	24.00	2272.00	1101.00	2.06	20.24
8	917.00	3125.00	21.00	2208.00	1169.00	1.89	18.53
9				Avg bulk density of soil		1.92	18.80

3.6 SAND REPLACEMENT METHOD TO EVALUATE IN-SITU DRY DENSITY:

This test is done to determine the in-situ dry density of soil by sand replacement method as per IS: 2720 (Part XXVIII) – 1974.

Fig 3.6 (a) Schematic view of Sand replacement apparatus

In laboratory test, a pit is excavated into the ground, through the hole in the plate, approximately 12 cm deep (same as the height of the calibrating can). The hole in the tray will guide the diameter of the pit to be made in the ground. The excavated soil is collected into the tray and weighed (W). Moisture content is then determined. The Sand penetrating cylinder with sand is weighed and finally after letting the sand to run into the pit by opening the slit of SPC, the weight of the SPC with the remaining sand (W4) is taken.

EXCEL SPREADSHEET DETERMINATION FOR SAND RELACEMENT METHOD

Input parameters

1. Weight of sand+ cone=A
2. Mean weight of sand in cone=B
3. Volume of calibrating container=C
4. Weight of sand+ cylinder after pouring=D
5. Weight of weight soil from hole=G
6. Weight of sand +cylinder after pouring into hole=H

Output parameters

1. Weight of sand filling container=A-B-D=E
2. Bulk density=E/C=F
3. Weight of sand into hole=A-B-H=I
4. Bulk density=G*F/I

Snap shot of the excel spread sheet determined for sand replacement method to evaluate in-situ dry density.(Table 3.6)

Aim :To determine the field density of soil using sand replacement test

IS 2720-part 28 (1974)

weight of cone+ sand (gm)	mean wt of sand in cone (gm)	volume of caliberating container(cc)	wt of sand +cylinder after pouring (gm)	wt of sand filling caliberating container (gm)	Bulk density (gm/cc)	weight of wet soil from the hole (gm)	wt of sand+ cylinder after pouring into hole (gm)	wt of sand in the hole (gm)	bulk density of soil (gm/cc)	Bulk unit weight of soil (KN/m^3)
12601.00	1104.00	2707.70	6042.00	5455.00	2.01	2145.00	9950.00	1547.00	2.79	27.40
12000.00	1100.00	2707.70	6000.00	4900.00	1.81	2100.00	9900.00	1000.00	3.80	37.28
11500.00	1111.00	2707.70	6040.00	4349.00	1.61	2210.00	9000.00	1389.00	2.56	25.07
11000.00	1000.00	2707.70	5990.00	4010.00	1.48	2010.00	9001.00	999.00	2.98	29.23
12000.00	1001.00	2707.70	6020.00	4979.00	1.84	2000.00	9100.00	1899.00	1.94	19.00
							Avg bulk density of soil		2.81	27.60

3.7 DIRCT SHEAR TEST:

The direct shear test is one of the most commonly used techniques for determining the shear strength parameters of soil.

The test is performed on three or four specimens from a relatively undisturbed soil sample .A specimen is placed in a shear box which has two stacked rings to hold the sample; the contact between the two rings is at approximately the mid-height of the sample. A confining stress is applied vertically to the specimen, and the upper ring is pulled laterally until the sample fails, or through a specified strain. The load applied and the strain induced is recorded at frequent intervals to determine a stress–strain curve for each confining stress (Das, B. M., 2010).

Excel Spread sheet for direct shear test:

Input parameters:

1. Proving ring reading=B
2. Proving ring constant=C
3. Area of specimen=A
4. Normal stress= Normal Load/A=F

Output parameters

1. Shear stress= B*C/A=τ
2. Φ, c are the arctan(slope) and intercept respectively of the plot of shear stress vs normal stress.

Algorithm to obtain the c, Φ values on a cell

Step 1: Shear stress is obtained for 5 different inputs and is averaged. $=y_1$.

Step 2: normal stress is taken corresponding to the 5 inputs, averaged $=x_1$

Step 3: slope (m) is calculated by $(y_1 - y_{(1st\ input)})/(x_1 - x_{1st\ input})$

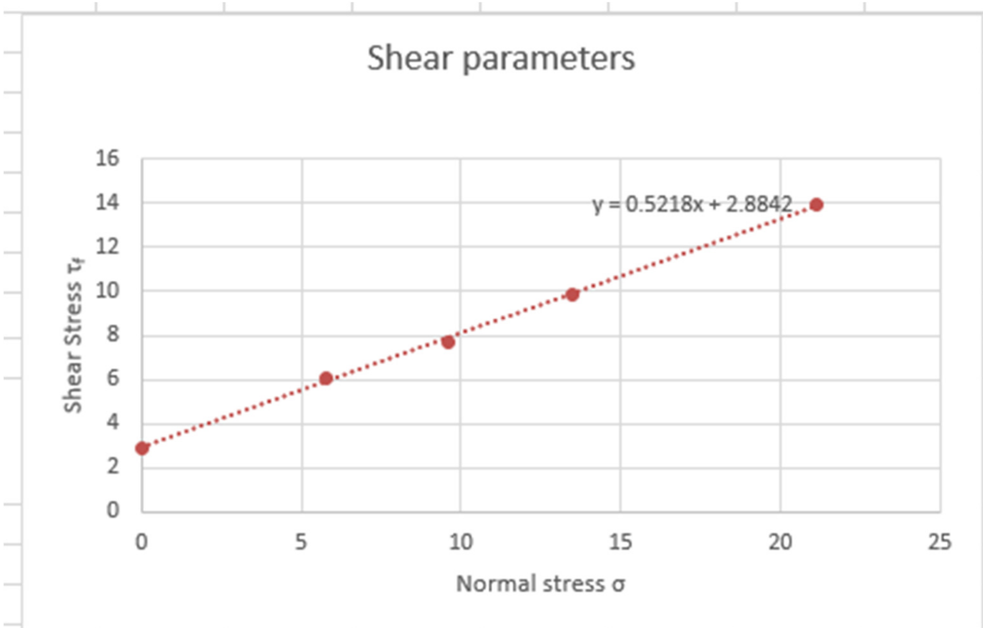
Step 4: Φ= arctan(m)

Step 5: $c=y_1 + m*(0-x_1)$

Excel spread sheet developed for direct shear(table 3.7)

	A	B	C	D	E	F	G	H	I	J	K
1		Test: Direct Shear Test									
2		AIM: To determine the shear parameters									
3		IS-2720-part11(1993)									
4											
5		Initial dimension of specimen			:in mm						
6		Height of specimen			25						
7		width of specimen			51						
8		Length of specimen			51						
9											
10		Proving ring constant			5						
11		Area (cm^2)			26.01						
12											
13	experiment no	Proving ring reading	Proving ring constant	shear Load (N)	Shear Stress (N/cm^2)	Normal Load (N)	Normal Stress (N/cm^2)	tan(ϕ)	ϕ(radian)	ϕ(degree	c
14	0.00	75.00	1.00	75.00	2.88	0.00	0.00	0.521846	0.480971	27.55763	2.88
15	1.00	157.50	1.00	157.50	6.06	150.00	5.77				
16	2.00	199.90	1.00	199.90	7.69	250.00	9.61				
17	3.00	257.60	1.00	257.60	9.90	350.00	13.46				
18	4.00	363.40	1.00	363.40	13.97	550.00	21.15				
19					8.10		10.00				

Graph obtained from previous table



3.8 Vane Shear Test

Vane Shear Test is performed to determine the shear parameters of soil of very soft to medium cohesion. The shear vane generally consists of four thin, equal-sized steel plates welded to a steel torque rod. First, the vane is pushed into the soil. Then torque is applied at the top of the torque rod to rotate the vane at a uniform speed. A cylinder of soil of height h and diameter d will resist the torque until the soil fails (Das, B. M., 2010). The un-drained shear strength of the soil can be calculated by the following formula

$T= \pi * c_u * [d^2h/2 + d^3/6]$

Input parameters

1. Height of specimen= A
2. Diameter of specimen= B
3. Spring Constant k = C
4. Dial Gauge= D

Output parameters:

1. Volume of specimen = π* $B^2A/4$=E
2. Final Torque = D*C=F
3. Shear strength = $F/(\pi)[B^2A/2 + B^3/6]$

Excel spread sheet developed for vein shear test(Table 3.8)

Aim: To determine the shear strength of soil using vane shear test						
IS 2720-part 30 (1980)						
Height of specimen (cm)	Diameter of specimen (cm)	Spring constant K (Pa) N-cm	Dial gauge Reading	Volume of specimen cm^3	Final torque (N-cm)	Shear strength τ_f KN/m^2)
7.30	3.80	1800.00	1.10	82.75	1980.00	38.45
7.30	3.80	1800.00	1.20	82.75	2160.00	41.95
7.30	3.80	1800.00	1.11	82.75	1998.00	38.80
7.30	3.80	1800.00	1.30	82.75	2340.00	45.45
7.30	3.80	1800.00	1.13	82.75	2034.00	39.50
				Avg shear strength		40.83

3.9 GRAIN SIZE DISTRIBUTION BY SIEVE ANALYSIS AND HYDROMETER ANALYSIS

Sieve Analysis:

Sieve analysis consists of passing the soil sample through a set of sieves that have progressively smaller openings. The size of the sieves are mentioned in Indian Standard codes IS-2720(part 4), 1985

Before passing the soil through the sieves the soil should be thoroughly broken from lumps and then passed. After the passing of soil, the mass ret ined should be cumulated and then formulated in a tabular format.

Snap shot of the spread sheet developed for sieve analysis (Table 3.9 a)

	Initial mass		1000	gm	
PARTICLE SIZE (mic)	PARTICLE SIZE (mm)	MASS RETAINED(g)	% RETAINED	CUM % RETAINED	% FINER
50000.00	50.00	0.00	0.00	0.00	100.00
40000.00	40.00	0.00	0.00	0.00	100.00
20000.00	20.00	0.00	0.00	0.00	100.00
10000.00	10.00	0.00	0.00	0.00	100.00
6250.00	6.25	0.00	0.00	0.00	100.00
4750.00	4.75	22.00	2.20	2.20	97.80
2000.00	2.00	21.00	2.10	4.30	95.70
1000.00	1.00	22.00	2.20	6.50	93.50
425.00	0.43	134.00	13.40	19.90	80.10
212.00	0.21	289.00	28.90	48.80	51.20
150.00	0.15	135.00	13.50	62.30	37.70
75.00	0.08	144.00	14.40	76.70	23.30
		767.00	gm		
	Residual	233.00	gm		

The residual mass that is the finer particles which pass through the sieves are collected and tested for hydrometer analysis.

Hydrometer analysis: Hydrometer analysis is based on the principle of sedimentation of soil grains in water. When a soil specimen is dispersed in water, the particles settle at different velocities, depending on their shape, size, weight, and the viscosity of the water.

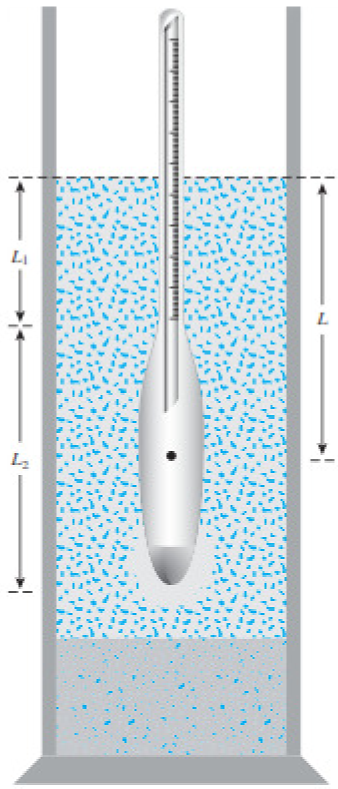


Fig 3.7 (a): Schematic diagram of apparatus of a Hydrometer analysis (Das, B. M., 2010)

Input parameters:

1. Hydrometer reading= L
2. Time = N
3. Distance from top of hydrometer to the mark=L_1
4. Length Of hydrometer bulb= L_2
5. Volume of Hydrometer Bulb= V
6. Cross sectional area of sedimentation cylinder= A

Output Parameters:

1. $H_e = L_1 + 0.5(L_2 - V/A) = M$
2. Square root(M/N) = O
3. Factor F= ((0.3*M)/(0.000000981*(N-1)))^0.5= P
4. Diameter= 10*O*P

5. % finer = N*(L*0.1/50)*(L-1)/(N-1)= R
6. Corrected % finer = 233/ 1000 *R

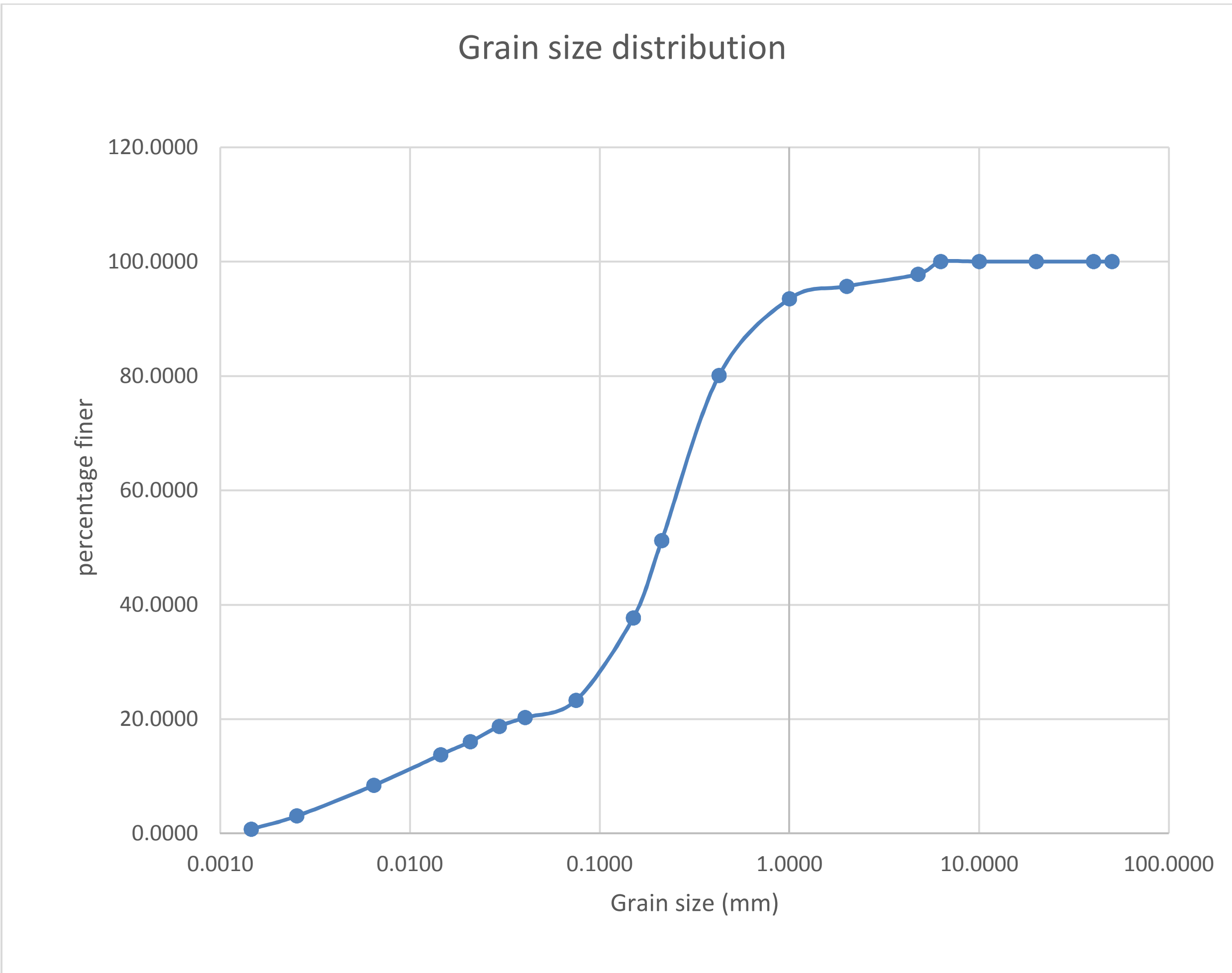
Snap Shot of the excel spread sheet determined for hydrometer analysis(table 3.9 (b))

V (cm^3)	η	G	M_D	t			
1000.00	8.85	2.56	1.00	27 ˚C			
Hyd Rdg	He	t	sqrt(He / t)	Factor F	diameter	% Finer	corrected
Rh	[cm]	minute			[mm]	per 1000gm	% finer
27.5	9.39	1.00	3.06	1317.15	0.04	86.97	20.26503
25.5	10.03	2.00	2.24	1317.15	0.03	80.41	18.73559
22	11.15	4.50	1.57	1317.15	0.02	68.92	16.05908
19	12.11	10.00	1.10	1317.15	0.01	59.08	13.76492
12	14.35	60.00	0.49	1317.15	0.01	36.10	8.411897
5	16.59	450.00	0.19	1317.15	0.00	13.13	3.058872
2	17.55	1440.00	0.11	1317.15	0.00	3.28	0.764718

Snap Shot of the Spread sheet combined for Hydrometer analysis and sieve analysis (Table 3.9 (c))

PARTICLE SIZE (mm)	% FINER
50.0000	100.0000
40.0000	100.0000
20.0000	100.0000
10.0000	100.0000
6.2500	100.0000
4.7500	97.8000
2.0000	95.7000
1.0000	93.5000
0.4250	80.1000
0.2120	51.2000
0.1500	37.7000
0.0750	23.3000
0.0404	20.2650
0.0295	18.7356
0.0207	16.0591
0.0145	13.7649
0.0064	8.4119
0.0025	3.0589
0.0015	0.7647

Grained Size Distribution obtained from above sieve analysis and hydrometer analysis



3.10 Constant Head Permeability test:

This test is used to determine the hydraulic conductivity of soil. A typical arrangement of the constant-head permeability test is shown below in fig 3.8 .The water supply at the inlet is adjusted in such a way that the difference of head between the inlet and the outlet remains constant during the test period. After a constant flow rate is established, water is collected in a graduated flask for a known duration (Das, B. M., 2010).

The volume of water collected is calculated by V= Avt

Where t= duration of water collection.

A= area of cross section of the soil specimen

Input parameters

1. Head Difference= B
2. Volume= D
3. Time= E

Output parameters:

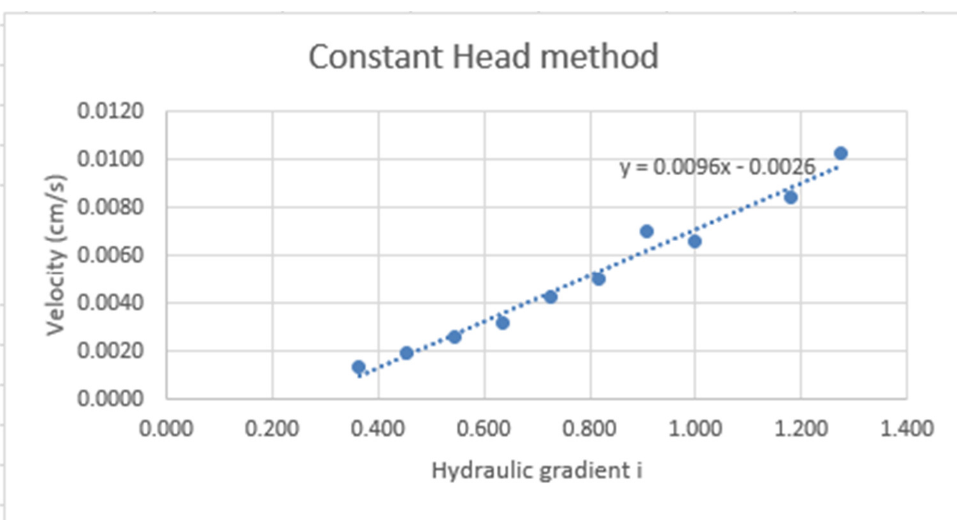
1. Hydraulic gradient i= B/Length = C
2. Velocity= D/Area*t= G
3. K=co-efficient of permeability= G/C

Snapshot of the excel Spread sheet determined for Constant head permeability test (Table 3.10)

Fluid Type	Water		Q=K.A.h/L
Inside diameter of sample tubing	4.5	cm	K=(Q*L)/(A.h)
Length of sand sample, L	15	cm	K=Q/(A*i) i=h/L
Area, A	18.10	sq. cm	K=v/i v=Q/A v=Velocity

Head difference, h (cm)	i=h/L	Volume, V (cc)	Time, t (sec)	Q=V/t (cc/s)	v=Q/A	K=v/i
4	0.364	2.1	120	0.0175	0.0013	0.003702
5	0.455	2.3	90	0.025556	0.0020	0.004325
6	0.545	3.5	105	0.033333	0.0026	0.004701
7	0.636	4.5	110	0.040909	0.0031	0.004945
8	0.727	5	90	0.055556	0.0043	0.005876
9	0.818	6	92	0.065217	0.0050	0.006132
10	0.909	5	55	0.090909	0.0070	0.007692
11	1.000	3	35	0.085714	0.0066	0.006593
13	1.182	5.5	50	0.11	0.0085	0.00716
14	1.273	6	45	0.133333	0.0103	0.008059
					Average	0.005918 6.29 E-03

Graph Obtained from the above input is



3.11 Variable Head Permeability test:

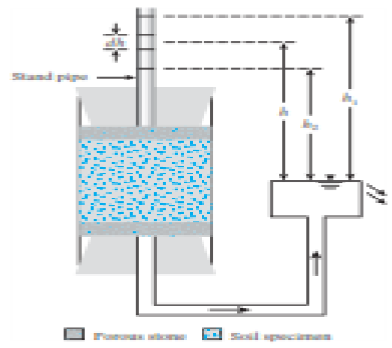


Fig. 3.11: Schematic view of Variable head Permeability Set-up

This test is also used to determine the hydraulic conductivity of soil. A typical arrangement of the falling-head permeability test is shown below. Water from a standpipe flows through the soil. The initial head difference at time t = 0 is recorded, and water is allowed to flow through the soil specimen such that the final head difference at time = completion of test is determined. Permeability is then calculated by

$K = 2.303\ (a*L/At)\ \log(h_1/h_2)$

A= Cross sectional area of specimen

a = Cross sectional area of stand pipe

t= time

h_1 , h_2 are the heights at beginning and end of test.

Input parameters:

1. h_1, h_2, t

Output parameter:

1. K

Snap shot of Excel Spread sheet developed for variable head permeability test(Table 3.11)

Fluid Type	Water	
Inside diameter of sample tubing	4.5	cm
Length of sand sample, L	15	cm
Area, Ac	18.10	sq. cm
Inside diameter of Burette	2	cm
Area, At	3.14	sq. cm

Lab Data											
h0 (cm)	48	50.5	59	60	50	49	55	52	60	65	
h1 (cm)	42.5	44	50.5	47	35	32	37	45	49	47	
h0/h1	1.13	1.15	1.17	1.28	1.43	1.53	1.49	1.16	1.22	1.38	
time (sec)	422	461	505	781	1162	1423	1270	421	644	1000	
K (cm/s)	7.51E-04	7.78E-04	8.02E-04	8.14E-04	7.99E-04	7.80E-04	8.13E-04	8.94E-04	8.19E-04	8.45E-04	8.10E-04

<u>3.12 Tri-axial shear test:</u>

1. Consolidated drained test(CD)
2. Consolidated un-drained test(CU)
3. Un-consolidated un-drained test(UU)

- In CD test, a confining pressure σ is applied from all direction and pore water is allowed to drain such that Consolidation occurs and pore water pressure becomes 0.

- Then an additional stress called deviator stress Δσ is applied in axial direction, water still being allowed to drain out Such that total stress=effective stress= σ + Δσ . Stress is increased till failure.

- In CU test, the pore water pressure at 2nd stage is not allowed to dissipate, thereby making effective stress=
total stress-pore water pressure= $\sigma + \Delta\sigma - \Delta u = \sigma + \Delta\sigma - u_f$

- In UU test, drainage is not allowed in both the stages, thereby effective stress=total-pore water pressure = $(\sigma + \Delta\sigma) - \Delta u = \sigma + \Delta\sigma - (u_f - u_i)$

*minor stress is obtained by putting $\Delta\sigma = 0$.

Input parameters:

Confining stress, confining stress+ deviator stress

Output parameters:

Shear parameters c and phi.

Algorithm used to develop the excel spread sheet

Step 1: the σ_i=confining stress and σ_f=final stress after deviator stress is applied is obtained according to the type of tri-axial test.

Step2: center and radius of the Mohr coulomb failure is calculated by $(\sigma_f+\sigma_i)/2$ and $(\sigma_f-\sigma_i)/2$

Step3: The half circle is then divided into 1800 strips from $\Theta=[0,\pi]$ with increment= $\pi/1800$

Step 4: $\Theta=0+\Theta_i$ where i=0 to 1800

Step 5: x_i=center +radius*cos Θ_i are found for all 1800 points.

Step6: y_i=radius*sin Θ_i are found for all 1800 points.

Step 7: m=slope=$\tan(0.5*\pi-\Theta_i)$ is calculated for all points

Step 8: c=intercept=: $y_i+m*(0-x_i)$ is calculated.

For two different mohr circle, let us take 2 different input parameters, and thereby we have the coordinates of 1800 points on the circle for the 2 circles.

At failure, c is equal for both circles.

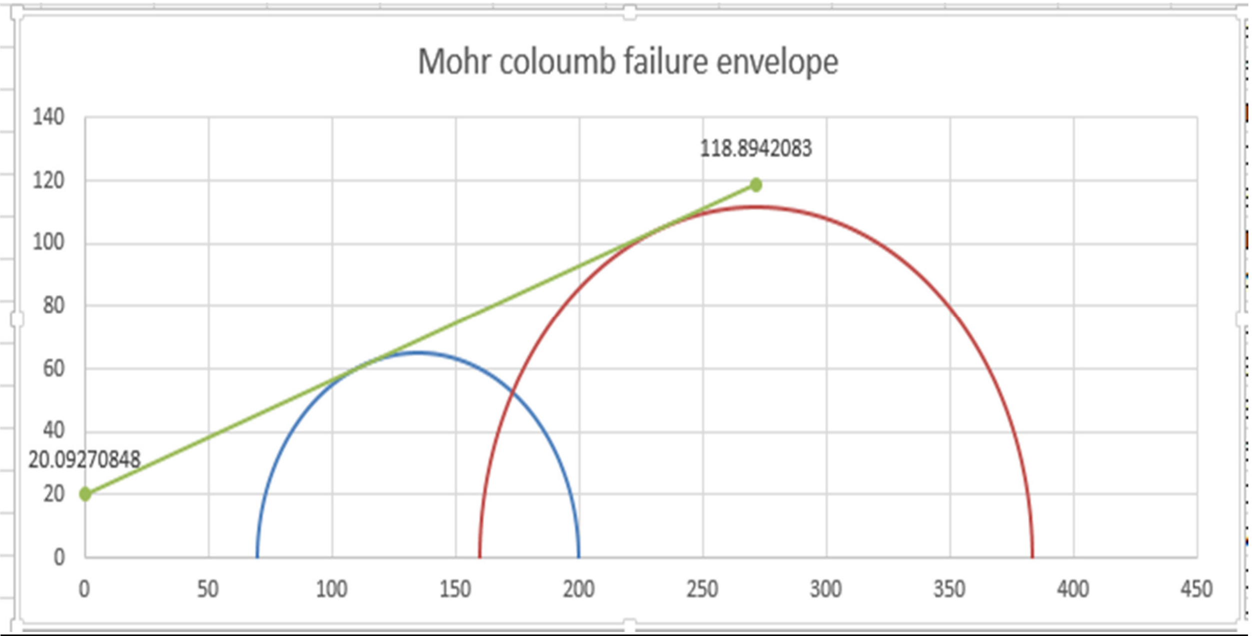
Step 9: (c1-c2)min is found for all 1800 points and assign (c1-c2)min =c
Step 10: if (c1-c2)=c, then c=c, else 0.

Step 11: if c=0, ϕ=slope=o, else Φ=arctan(mi)

Calculation spread sheet of triaxial shear test(Table 3.12)

1.18438	110.5034	60.20727	229.6347	103.5102	0.406871365	15.24661101	10.07842826	5.168182747	5.168182747	0	0
1.187522	110.6927	60.28393	229.9601	103.642	0.403214362	15.65106807	10.91879752	4.732270549	4.732270549	0	0
1.190664	110.8822	60.36	230.2859	103.7728	0.399566612	16.05519258	11.75822813	4.296964455	4.296964455	0	0
1.193805	111.0719	60.43547	230.6121	103.9025	0.395928009	16.45899377	12.59674017	3.8622536	3.8622536	0	0
1.196947	111.2619	60.51035	230.9387	104.0312	0.392298446	16.86248079	13.4343536	3.428127192	3.428127192	0	0
1.200088	111.4521	60.58462	231.2657	104.1589	0.388677819	17.26566276	14.27108825	2.994574512	2.994574512	0	0
1.20323	111.6425	60.6583	231.5932	104.2856	0.385066022	17.66854874	15.10696383	2.561584909	2.561584909	0	0
1.206372	111.8332	60.73138	231.921	104.4113	0.381462954	18.07114776	15.94199996	2.129147802	2.129147802	0	0
1.209513	112.0241	60.80386	232.2492	104.5359	0.377868512	18.47346877	16.77621609	1.697252678	1.697252678	0	0
1.212655	112.2153	60.87574	232.5778	104.6594	0.374282593	18.8755207	17.60963161	1.265889092	1.265889092	0	0
1.215796	112.4066	60.94702	232.9068	104.782	0.370705098	19.27731242	18.44226576	0.835046664	0.835046664	0	0
1.218938	112.5982	61.0177	233.2362	104.9035	0.367135925	19.67885277	19.27413769	0.404715076	0.404715076	0	0
1.22208	112.79	61.08778	233.5659	105.024	0.363574976	20.08015052	20.10526644	-0.025115924	0.025115924	20.09271	0.348717
1.225221	112.982	61.15725	233.896	105.1434	0.360022153	20.48121441	20.93567094	-0.454456527	0.454456527	0	0
1.228363	113.1743	61.22612	234.2265	105.2618	0.356477358	20.88205316	21.76537002	-0.883316862	0.883316862	0	0
1.231504	113.3667	61.29438	234.5574	105.3792	0.352940493	21.28267541	22.59438241	-1.311707	1.311707	0	0
1.234646	113.5594	61.36205	234.8887	105.4955	0.349411463	21.68308978	23.42272673	-1.739636951	1.739636951	0	0
1.237788	113.7523	61.4291	235.2203	105.6108	0.345890172	22.08330486	24.25042153	-2.16711667	2.16711667	0	0
1.240929	113.9454	61.49555	235.5522	105.725	0.342376526	22.48332917	25.07748522	-2.594156054	2.594156054	0	0
1.244071	114.1387	61.56139	235.8846	105.8382	0.33887043	22.88317122	25.90393617	-3.020764945	3.020764945	0	0
1.247212	114.3322	61.62662	236.2172	105.9504	0.335371791	23.28283948	26.72979261	-3.446953129	3.446953129	0	0
1.250354	114.5259	61.69125	236.5503	106.0615	0.331880517	23.68234237	27.55507271	-3.872730341	3.872730341	0	0
1.253495	114.7198	61.75527	236.8836	106.1716	0.328396516	24.08168828	28.37979455	-4.298106262	4.298106262	0	0

Mohr coulomb failure envelope (graph of σ vs τ)



3.11 Load bearing capacity of shallow foundation:

Foundation is the lowest part of a structure. It transfers the load of the structure to the soil on which it is rests. A good foundation transfers the load throughout the soil evenly so that failure does not occur. Overstressing the soil can result in either excessive settlement or shear failure of the soil. Hence, Bearing capacity of soil is important for engineers who design the foundation.

Input parameters:

1. Type of foundation
2. Width of foundation
3. Depth of foundation
4. Angle of friction , phi
5. Saturated unit weight of soil
6. Cohesion of soil

7. Water table depth

Formula used:

1. Terzaghi equation:

   $Q_u = q_c + q_q + q_\Upsilon$

   Where $q_c = cNc$

   $q_q = qNq$

   $q_\Upsilon = kB\Upsilon N_\Upsilon$, k=0.3 for circular, 0.4 for square and 0.5 for rectangular

$$N_q = \frac{e^{2\left(\frac{3\pi}{4}-\frac{\phi}{2}\right)\tan\phi}}{2\cos\left(45+\frac{\phi}{2}\right)^2}$$

$$N_c = (N_q - 1)\cot\phi$$

$$N_\gamma \approx 1.8(N_q - 1)\cot\phi(\tan\phi)^2$$

2. For water table

   W'= water table factor is given by

   For unit weight part->W'= if(W>(B+D),1,if(W<D,0.5, 0.5*(1+(W-D)/B))

   For surcharge part→ W'=if(W>(D+B),1,if(W<D,0.5(Df-D)+D, 0.5*(1+(W-D)/B)))

Algorithm used

Step1: let us assign the value 1,2,3 as

1=Circular Footing

2=Square Footing

3=Rectangular Footing

Step2: enter input parameters (W)width, (D)depth and (ϕ)shear parameter.

Step 3: Calculate Nc, Nq and NϒΥ as per terzaghi's equations

Step 4: enter the input parameters unit weight(ϒ), water table (w), cohesion (c)

Step 5: calculate water table factor W'

For unit weight part->W'= if(W>(B+D),1,if(W<D,0.5, 0.5*(1+(W-D)/B))

For surcharge part→ W'=if(W>(D+B),1,if(W<D,0.5(Df-D)+D, 0.5*(1+(W-D)/B)))

Step 6: if step1=1, q_u=1.3cNc+qNq+0.3BϒN$_\Upsilon$, else (if(step1=2, 1.3cNc+qNq+0.4B ϒN$_\Upsilon$,1.3cNc+qNq+0.5 ϒN$_\Upsilon$

Excel Spread sheet developed to determine the ultimate load bearing capacity of foundation(table 3.13)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Type 1=Circular Footing			Nq=bearing capacity factor for surcharge									
2	Type 2=Square Footing			Nc= Bearing capacity factor for cohesion									
3	Type 3=Rectangular Footing			NY= Bearing capacity factor for unit weight									
4	IS 6403(1981)												
5	Type	Width B(n	Depth D(n	Φ (degree	Φ (radian)	N_q as per Terzaghi	N_c as per Terzaghi	N_Υ as per Terzaghi	saturated unit weight ϒ(KN/m^3)	Cohesion c(KN/m3)	Ground water table (m)	water table factor W'	Ultimate Bearing capacity
6	3.00	2.10	0.10	35.00	0.61	41.21	57.47	50.65	20.00	20.00	3.00	1.00	2214.82
7	2.00	2.20	0.20	36.00	0.63	46.89	63.20	59.97	22.00	20.00	0.10	0.50	3010.66
8	1.00	2.30	0.30	37.00	0.65	53.48	69.69	71.14	21.00	20.00	2.50	0.98	3448.85
9	3.00	0.40	0.40	0.01	1.04	5.70	0.00	20.00	23.00	23.00	4.00	1.00	107.67
10	2.00	1.10	0.50	0.01	1.05	5.75	0.00	20.00	21.00	24.00	0.30	0.50	245.23
11	1.00	3.00	0.60	0.01	1.06	5.80	0.00	20.00	20.00	25.00	1.00	0.57	669.59

Conclusions

Based on the theory and procedure of some commonly used geotechnical laboratory test, an excel spreadsheet has been developed and the conclusions are the following:

- ✓ An honest effort is being made to determine the output of some geotechnical engineering laboratory experiments in an excel spreadsheet in a comprehensive manner.
- ✓ The results are found to be consistent with previously obtained data

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